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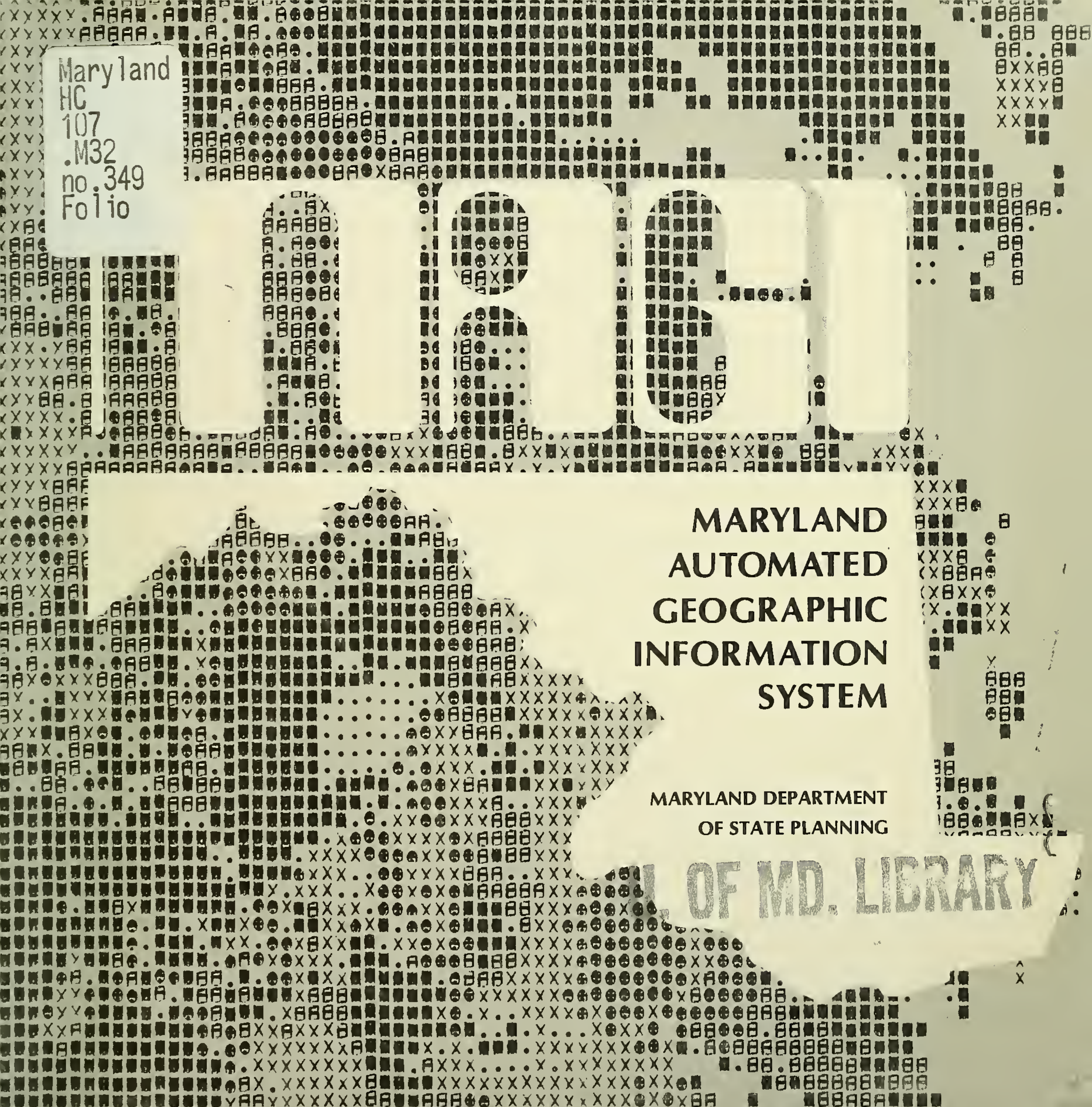

MAGI

MARYLAND AUTOMATED GEOGRAPHIC INFORMATION SYSTEM

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OF STATE PLANNING

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MARYLAND DEPARTMENT OF STATE PLANNING

301 W. Preston St.
Baltimore, Maryland 21201

JANUARY, 1979

June, 1979

MEMORANDUM

TO: RECIPIENT

FROM: MARYLAND DEPARTMENT OF STATE PLANNING
COMPREHENSIVE STATE PLANNING DIVISION

Please find enclosed for your information and use a booklet describing the Maryland Automated Geographic Information (MAGI) System. This booklet describes the operation of and improvements made to the MAGI System since its establishment in 1974. Recent planning applications of the System by a variety of users are also described. If you have no immediate need for this booklet, please pass it on to appropriate persons within your organization.

Inquiries about the operation or use of the MAGI System should be addressed to:

Ms. Susan Alderman
or Mr. Dale Johnson
(301) 383-3067

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Preface

It has only been within the past five to ten years that applications of the state-of-the-art technologies of computer mapping and resource information systems have been realized on an operating basis. The capabilities of these systems, in conjunction with increasing pressures and new mandates to address land use and natural resources planning, have resulted in the creation of a growing number of such systems. State and regional governments have largely brought computer capabilities in this regard from the domain of research and development into the dynamic world of practical analysis. In April, 1974, the Maryland Department of State Planning acquired the capability for the State to perform such analysis by the establishment of the Maryland Automated Geographic Information (MAGI) System. By 1975, a survey by the U.S. Department of the Interior rated the MAGI System as having *the most comprehensive capability for statewide manipulation of spatial data currently in existence.*

Since 1975, several other large computer mapping and information systems have been created. However, the goal of the MAGI System is not to compete with other systems as a measure of its worth but rather to continue to serve as an efficient and accurate tool to address the land use and natural resource planning problems unique to Maryland.

The purpose of this report is to present a brief but comprehensive explanation of the structure and applications of the MAGI System to date. It is expected that the report will benefit three audiences: (1) those who may have local applications for which the System may be suitable; (2) those who are contemplating creation of a system and who are in need of general information about structure and capabilities; and (3) those working with established systems who are in need of documentation on comparable systems to keep abreast of progress in the field. While an attempt has been made to avoid jargon, or at least to define special terms as they appear, this report will undoubtedly be easier to comprehend for those who have some experience with computer systems.

The report is organized into two major discussions: the structure of the System and the applications which have been made. The System structure discussion details the data base, methods of data input, System operation, software capabilities, output products, ancillarly capabilities, and System costs. For many who receive this report, the explanation of the MAGI System will be sufficient; however, for some additional information needs will exist. We encourage further inquiry about MAGI and hope that others will share with us information about their related efforts.

Introduction

The Maryland Automated Geographic Information (MAGI) System is a computer-assisted system for the storage, retrieval, manipulation, and display of geographic grid-referenced data. The MAGI System was developed by the Environmental Systems Research Institute of Redlands, California for the Maryland Department of State Planning. Implemented in 1974, the System was designed to assist the Department in the preparation of its Generalized State Land Use Plan. Since that time, the System has been expanded and significantly improved, resulting in greater structural efficiency, lower operating costs, and greater user flexibility. The System has been used extensively by other State agencies for land and water resources analyses.

As initially developed, the MAGI System consisted of a central State-wide data base containing nearly 88,000 grid cells of 91.8 acres and a package of linked software subroutines. As now comprised, the data base includes not only computer stored data but also data base maps, technical manuals, supporting text descriptions (library lists), and tabulations. The MAGI software package is capable of manipulating data at any size and scale, and other larger-scale but limited area data bases have subsequently been structured for special analyses within the State.

Data Base

Geographic data for the State-wide data base are chosen according to several criteria: coverage, currency, quality, scale, and suitability to grid referencing. Data are gathered from various Federal, State, and local government agencies and are reformatted to county base maps at a scale of 1:63,360 (1 inch = 1 mile), or 1:62,500 where topographic maps serve as the base. The State Plane Coordinate (SPC) System established for the U.S. is used as the grid referencing base because (1) the entire State is included in one SPC zone, (2) the majority of available data is compiled to the Lambert Conformal Conic projection used for the SPC System, and (3) absolute data accuracy for distances and areas, such as decimal latitude/longitude, is not warranted for the generalized analysis of State-wide data.

MAGI System data variables represent distributions of physical, cultural, and areal data described by polygon, point, and line features. All System data are coded and input as positive integers and are structured to allow maximum flexibility for user interpretation. An example of this data structure is presented in the Appendix. The value of storing data in the System without specifically assigned values is that it allows the user flexibility to rank, combine, or assign weightings to the array of codes for each unique application of the data to a planning problem. Also, for several detailed variables, multiple data codes, or *levels of occurrence*, are identified and stored (additional discussion of these levels is found under Data Entry).

In Table 1 the current State-wide data variables are listed by type and level of occurrence encoded for the physical, cultural, and areal data groups. Table 1 also indicates the scale of the raw data either before compilation to county base maps or as the data was directly encoded.

In addition to computerized data input and retrieval, an effort was made to make the base data available to users in standard map form. Most of the MAGI data variables were compiled on or combined with standardized grid cell base maps for each county at a scale of 1:63,360 (1 inch = 1 mile). For several major data variables, detailed manuals were also prepared which describe the source, data, coverage, and scale of the original data; standardization of classifications; methods of reformatting to a standard encoding scale; and tables of interpretations for use with computer mapping. The MAGI data base is, therefore, available as a county-scale polygon maps with the grid system overlain, as well as via computer storage and retrieval.

Another integral part of the System's data management is the periodic updating of the more dynamic data variables. Updates are performed at one to four year intervals for several of the cultural variables, especially land use, historic sites, transportation, and sewer/water service areas. The update interval depends upon the frequency of use of the variable, the availability of current data, and the relative dynamic nature of the variable.

The following sections highlight the type of information contained in the State-wide data base for the physical, cultural, and areal variables and several other variables currently being added to the System.

Physical Data Variables

Natural Soil Groups. Highly detailed county soil surveys were obtained from the USDA Soil Conservation Service. More than 300 soil series were reformatted into 42 natural soil groups, a planning designation permitting discrete data interpretation. The natural soil groups are arranged in order of increasing limitations for various uses, based primarily on drainage, productivity, depth to bedrock and watertable, permeability, susceptibility to flooding, stoniness, and slope.

Topographic Slope. Percent slope is used as an indicator of topography. County maps were encoded delineating areas where slope ranges from 0-3, 3-10, 10-20, and greater than 20%.

Engineering Geology. Individual geologic formations are numbered sequentially within physiographic provinces. Where possible, the formations are subdivided by facies. Formation codes can be referenced to interpretation tables for hardness, overburden thickness, excavation requirements, stability of cut faces, and extent of weathering.

Mineral Resources. U.S. and Maryland Geological Survey data were used to locate major metallic and nonmetallic mineral and mineral fuel deposits with development potential. The inventoried resources include active and inactive deep and strip coal mines; developing, operating, or storage gas fields; sand and gravel, clay and shale, and peat pits; stone quarries; green sand and diatomite areas; and copper and gold deposits.

Surficial Hydrology (Water Quality). Water quality characteristics were compiled for all second and third-order stream systems in the State. The original data on quality was obtained from a 1972 Water Resources Administration classification; and areas of existing oyster and clam beds and shellfish harvesting regions were also added. The classification distinguishes water with quality suitable for water contact recreation and aquatic life (Class I), shellfish harvesting (Class II), natural trout (Class III), and recreational trout (Class IV). Many portions of State waters do not presently meet the standards for their respective water classes due to pollution. The encoded classification therefore indicates those areas meeting and not meeting quality standards and oyster and clam bed areas closed to harvesting.

Vegetation Cover Types. Utilizing an extensive inventory of vegetation cover types produced by the State in 1949-1951, high altitude aerial photography for 1973 was used to produce maps depicting areas by forest types. Nearly two dozen forest types are included in the classification.

Unique Natural Features and Scenic Areas. Data on unique natural features and scenic areas were compiled from two extensive inventories by the Department of State Planning, in conjunction with the Smithsonian Institution, and the Department of Natural Resources. These inventories were based on questionnaires, publications, and field observation. Ponds, springs, caves, archeological sites, wilderness areas, stream valleys, natural areas, and wildlife habitats were included, as well as nest sites of eagles, osprey, and heron. A State-sponsored program creating a Maryland champion tree inventory provided additional data. Each mapped item is designated by a unique numerical identifier which can be referenced to a computerized listing - *library list* - describing the area, ownership, location, description, and other important features of the site.

Endangered Species. Habitat locations were inventoried by the Maryland Wildlife Administration for a number of endangered species including the Delmarva fox squirrel, American bald eagles, the great blue heron, the Eastern tiger salamander, the Jefferson salamander, osprey, and bog turtles. For the bog turtle, both existing colonies and potential habitats were mapped.

Bay Bathymetry. The mean depth in feet of the area covered by each cell was encoded from U.S. Coast and Geodetic Survey maps of the Chesapeake Bay.

Cultural Data Variables

1970 Land Use. In conjunction with the USGS Geographical Application Program, a 1:125,000 (1 inch = 2 miles) land use inventory was prepared from 1970 high altitude color and color infrared aerial photography acquired from NASA. The inventory indicated 28 separate types of land cover within a Level II classification (after Anderson et *al.*). Base maps were compiled by region. The minimum size of a land cover type mapped was approximately 40 acres.

1973 Land Use. The availability of high altitude color infrared coverage of the State permitted a more detailed land use inventory to be compiled. The 1973 inventory was mapped by county at a scale of 1:63,360 (1 inch = 1 mile). The Level III classification employed for this inventory includes 56 separate types of land cover. The minimum mapping unit was refined to 10 acres.

1978 Land Use. The 1978 land use inventory was compiled in the same manner as the 1973 inventory. However, the polygon shapes at the minimum mapping unit were delineated in greater detail, and the Level III classification was expanded to include 79 separate types of land cover.

1973 County Sewer/Water Service Areas. County plans for sewer and water service were combined and coded according to the planned staging of both facilities. Service stages include (1) existing service areas or areas under construction, (2) immediate priority areas or areas planned for service within 5 to 6 years, (3) service planned within 10 years, (4) service planned within 20 years, and (5) service planned beyond 20 years or no service currently planned.

1976 County Sewer/Water Service Areas. By 1976, nearly two-thirds of the counties produced new sewer and water service plans, many indicating more detailed stages. For these counties, planned service areas were updated and the stages were grouped as follows: (1) existing service areas or areas under construction, (2) service in final planning, (3) areas of immediate service priority, (4) areas planned for service within 3 to 5 years, (5) areas planned for service within 6 to 10 years, (6) areas planned for service beyond 10 years and/or from 11 to 20 years, (7) service planned beyond 20 years or no service planned, and (8) existing trunk lines in counties where service areas are not shown.

1980 County Comprehensive Plans. More than 60 types of planned uses were mapped from existing county comprehensive plans. The plan code indicates the planned use, the plan date and status, the planning period, and the source of the data.

Transportation Facilities (Nonhighway) Various sources were used to map utility and transportation-related facilities, including existing airports, heliports, railroads, gas and oil pipelines, transmissions lines, ship channels, and planned rapid and commuter rail lines.

Highways. The highway variable indicates several characteristics of the highest functional class roads located in each cell. The code includes the route number, segment number, functional class, and junction/intersection characteristics of the highways. The highway codes are also keyed to annually updated statistical and road quality data compiled by the State Highway Administration.

Public Properties. A thorough inventory of State and federal properties was compiled from property listings and tax maps. In addition, major county and municipal ownerships of parks and watershed protection areas are included. The inventory code indicates which level of government and which agency holds the property. The inventory is also keyed to a library listing which contains information on the size, ownership, location, and use of the parcels.

Historic Sites. An extensive inventory of approximately 13,000 historic sites and districts was compiled from the records of the Maryland Historical Trust. The site code, which is keyed to a detailed description in a library listing, includes a site identifier, the county code, historic registry status, date (period), and function. The sites are also keyed to highly detailed descriptions in the files of the Trust.

Outdoor Recreation/Open Space. The Department developed and maintains an inventory of more than 5280 outdoor recreation areas and open spaces. The inventory is comprised of both maps and an extensive library list. The inventory provides comprehensive information about the location and characteristics of Federal, State, county, regional, municipal, private, and quasi-public recreation and open space areas. The library information details the location, ownership, area, type of facility, activities available, type of funding and acquisition, and user characteristics for each site.

Areal Data Variables

For each cell in the State-wide data base, the county, watershed (stream segment), census tract/minor civil division, and election district to which it belongs is encoded. These areal data variables serve several purposes for the MAGI System. Primarily, areal units serve to disaggregate State-wide data to common units for which other data are available. For example, MAGI System output which describes a particular condition can be compared to socio-economic data collected elsewhere for election districts or census tracts/minor civil divisions. Areal units can also be used directly to define a sub-area for data analysis from the State-wide data base. For example, data for metropolitan areas can be manipulated independently of rural areas by specifying only certain census tracts, or data for the Coastal Plain can likewise be separated by specifying only those counties in the Coastal Plain. Finally, the areal units can be used in conjunction with a System routine (described below) to produce tabulations of mapped output by the areal units.

New System Variables

Edge Effect. As basic wildlife planning data which is currently being input into the MAGI System, the Maryland Wildlife Administration is determining the occurrence of vegetation edge. This variable indicates the occurrence of forest edge and vegetated strips such as hedgerows according to intervals of linear edge. The intervals are: no edge, less than 2000 feet, and greater than 2000 feet of linear edge. Vegetation edge is an important determinant of wildlife habitat for many species.

Stream Classification. An update to the surface hydrology variable by the Maryland Wildlife Administration will detail the hierarchy of water types across the State and the degree of forestation alongside each. As with edge effect, this variable will help determine wildlife habitat. The hierarchy indicates the ocean zone; coastal, salt estuarine, brackish estuarine, slightly brackish estuarine, and fresh estuarine bays; inland open fresh water impoundments greater than and less than 10 acres; 11 classes of streams according to the Van Deusen System; springs; and canals and ditches. The degrees of forestation include nonforested, intermittently forested, half-forested, and forested.

Archaeological Sites. The Department is working with the Division of Archaeology of the Maryland Geological Survey to establish a computerized inventory and mapping of the known archaeological sites in the State. A detailed library list similar to that for historic sites is also in progress. The inventory will also include areas where detailed field work has determined that no sites are located. A pilot study in the Monocacy River area of Frederick and Carroll Counties has identified 550 sites. A new technique of encoding is being employed for this variable: sites encoded at the large-scale (see data entry below) are referenced to the 91.8 acre grid cells. The use of archaeological data is subject to the disclosure requirements of the State Archaeologist.

Table 1: CURRENT MAGI SYSTEM STATE-WIDE DATA VARIABLES

VARIABLE	TYPE OF DATA DISTRIBUTION	SCALE OF RAW DATA	LEVEL OF OCCURRENCE ENCODED[1]
PHYSICAL DATA VARIABLES:			
Natural Soil Groups	Polygon	1:15,840; 1:20,000	P,S,T
Topographic Slope	Polygon	1:63,360	P,S
Engineering Geology	Polygon	1:63,360	P,S
Surficial Hydrology (Water Quality)	Polygon	1:63,500	P
Mineral Resources	Polygon, Point	Previously unmapped	P
Vegetation Cover Types	Polygon	1:24,000, 1 63,360	P,S
Unique Natural Features and Scenic Areas	Polygon, Point, Line	Previously unmapped	P,S
Endangered Species	Polygon, Point	1:15,840; other various scales	P,S
Bay Bathymetry	Point		P
CULTURAL DATA VARIABLES			
1970 Land Use	Polygon	1:100,000	P,S
1973 Land Use	Polygon	1:130,000	P,S,T
1978 Land Use	Polygon	1:63,360	P,S,T[2]
1973 County Sewer/Water Service Areas	Polygon	Various scales	P
1976 County Sewer/Water Service Areas	Polygon	Various scales	P
Transportation Facilities (Non-Highway)	Line, Polygon, Point	Various scales	P,S
1980 County Comprehensive Plans	Polygon	1:63,360	P,S,T
Public Properties	Polygon, Point	1:12,500	P,S
Historic Sites	Point, Polygon	1:63,360	P,S,T
Highways	Line, Point	1:63,360	P,S
Outdoor Recreation/Open Space	Polygon, Point, Line	1:63,360; other various scales	P
AREAL DATA VARIABLES:			
County	Polygon	1:63,360	P
Watershed (Stream Segment)	Polygon	1:62,500	P
Election District	Polygon	1:62,500	P
Census Tract/Minor Civil Division (MCD)	Polygon	1:63,360	P
Cell Identified (ROW/Column Coordinate)	N/A	N/A	N/A
NEW SYSTEM VARIABLES:			
Edge Effect	Polygon	1:63,360	P
Stream Classification	Polygon, Line	1:24,000	P,S,T,Q
Archaeological Sites	Point, Polygon	1:24,000	P,S,T,Q

[1] P = Primary level of occurrence.
S = Secondary level of occurrence.
T = Tertiary level of occurrence.
Q = Quarternary level of occurrence.

[2] Also indicates the percentage of the cell in each level of occurrence.

NOTE: All checks are made on the primary occurance

Data Entry

County data base maps at a scale of 1 inch = 1 mile are encoded using both manual and automatic techniques. For manually encoded data, a 10,000 foot grid, corresponding to Maryland State Coordinate Grid Lines, is used as a reference for a smaller acetate grid of 2000-feet square cells (91.8 acres). The smaller grid is overlain on the State Plane grid and the rows and columns of the small grid are numbered sequentially, relative to an origin point. The origin points become a standard reference for merging each county data set into the State-wide data matrix. Therefore, each intersection of a row and column represents a unique 2000 × 2000-foot cell (Figure 1). The State-wide data base is comprised of nearly 88,000 of these 91.8 acre cells, each cell containing data values for the variables listed in Table 1.

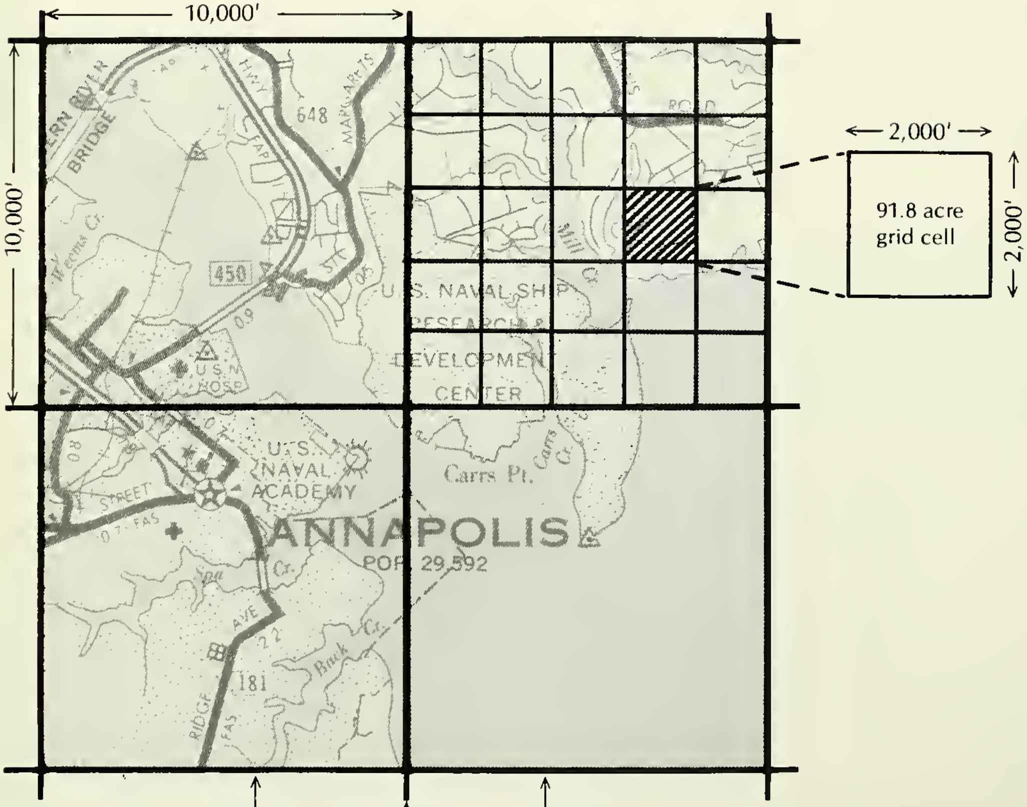
The encoding process involves the visual identification of the largest data polygon which is outlined by the 3/8 inch-square, 2000-foot grid lines on the 1:63,360 data maps. The dominant or largest data polygon becomes the primary occurrence, and smaller data polygons are encoded as secondary or tertiary occurrences. These multiple levels of encoding are used where the data is finely textured such that there are several data occurrences in a cell. The benefits of using this multiple level encoding technique are that it permits some refinement in identification of the data polygons in a cell and that it permits some relative ordering of which of the data polygons cover more of the cell. While the actual percentage of cover and the distribution of data within the cell are not known, the multiple levels of encoding nevertheless provide a more accurate picture of the nature of the data within the area of the cell than would a one-code generalization.

Initially, when primary, secondary, or tertiary data occurrences were encoded for a variable, they were structured as separate data files. These multiple levels of encoding are now structured in one file per variable within the limits of a 12-digit maximum code. An advantage of the *one file per variable* structure is that more data variables can be stored in the same amount of memory. Consequently, the collapsed storage results in reduced computer execution time and costs. For example, natural soil groups were originally encoded as three files of three digits each but are now structured in one nine-digit file. A FORTRAN modular function allows the primary, secondary, or tertiary data codes to be retrieved and manipulated independently.

Larger-scale data encoded for special studies via MAGI have most often been encoded directly from detailed base maps at the various scales at which the data was originally compiled. The grid system which is employed for these data bases consists of a 20 part subdivision of each 91.8 acre cell. In order to correct for the scale distortion found in the 91.8 acre cells which is due to the rectangular dimensions of a standard line printer character (1/10 inch horizontal × 1/8 inch vertical), the 20 larger-scale data cells are arranged within each 91.8 acre cell by 4 rows of 5 cells each. Each large-scale cell is therefore 400 feet across by 500 feet down, covering an area of 4.57 acres. The relationship and dimensions of the large-scale data cells and the 91.8 acre data cells is illustrated in Figure 2.

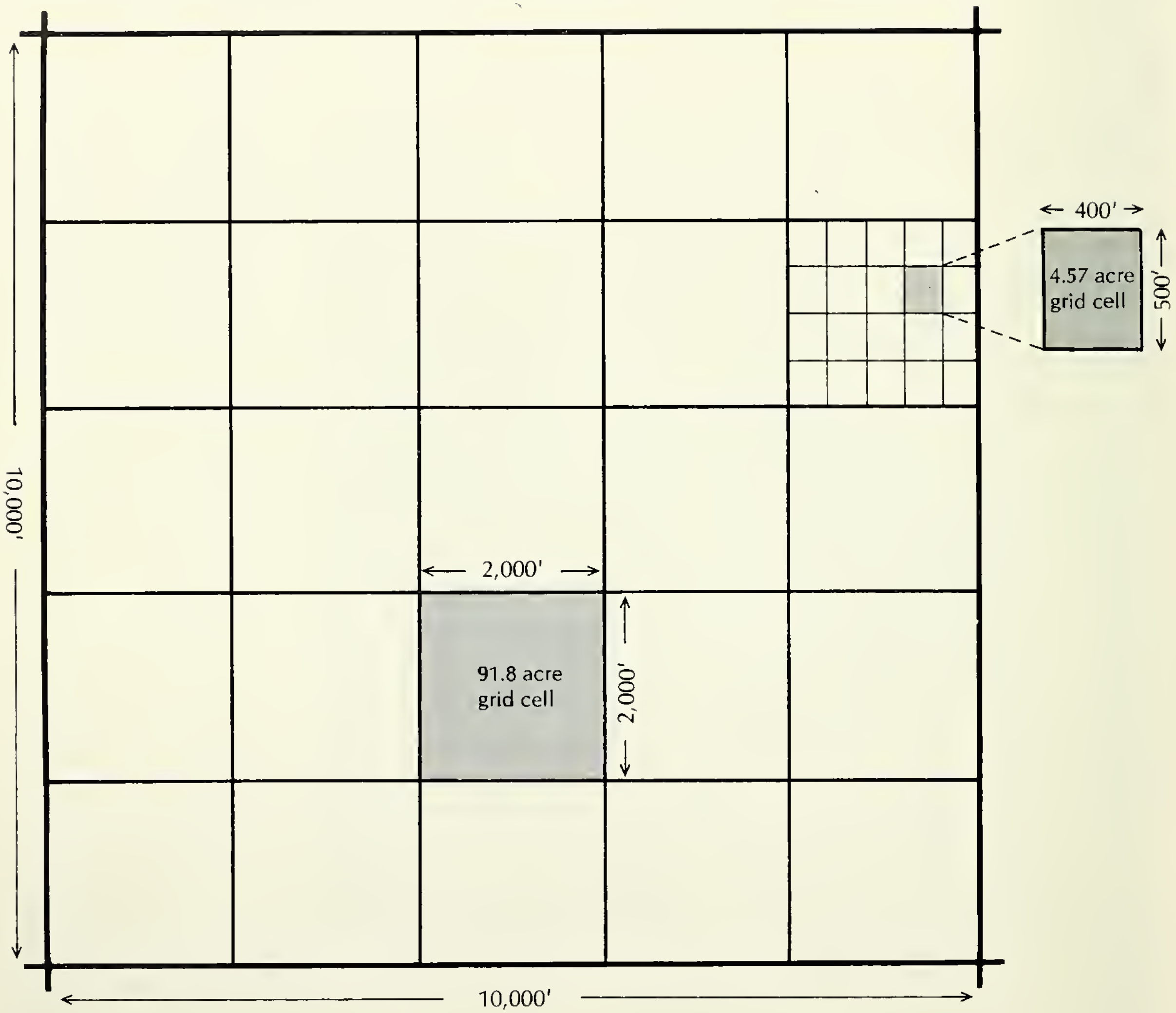
The 91.8 acre and 4.57 acre grid cells commonly used with MAGI were chosen after consideration of data detail, cost, time, and level of analysis, although the *scale-independence* of the System allows other grid sizes to be constructed. Accordingly, potential users of MAGI can choose the scale for special projects after consideration of such factors as the quality, scale, and availability of data.

Figure 1: MAGI GRID USED FOR ENCODING



Each 91.8 acre grid is ⅜″ square on the 1:63,360 (1″ = 1 mile) base maps.

Figure 2: RELATIONSHIP OF 4.57 AND 91.8 ACRE CELLS



Each 91.8 acre grid cell contains 20 4.57 acre cells and is 1'' square on the 1:24,000 topographic maps.

System Operation

The MAGI System was designed for maximum in-house operation by Departmental staff. The staff perform all System work except input of data via remote telecommunications terminals. These terminals tie in, through dial-up access, to the UNIVAC 1108 at the College Park campus of the University of Maryland. The terminals are used primarily for System operation, while output maps are produced on high speed line printers at the University. MAGI System software are operated through the UNIVAC Exec 8 Control Language, a highly efficient and easily learned medium for the use of data and program files. The entire System is operated in demand mode (again, except for batch input of data sets) and is always on-line through a small group of program files maintained in active mass storage. Data files and output files, as well as back-up versions of program files, are stored on magnetic tape for retrieval, as required.

In addition to the project coordinator and the System programmer and operator, a small data maintenance staff is retained for data verification and updating, and for structuring and encoding of new data. The services of a technical computer consultant at College Park are also available to the Department. Other user services available at cost through the University include keypunching, technical manuals and a program library, and regular delivery of output from College Park to Baltimore.

Software

The MAGI System software package consists of a set of inter-related FORTRAN programs initially developed for the Department and of a set of smaller routines developed by Department staff. Two main functions are served by the software: (1) the creation and maintenance of the System data base, and (2) the retrieval, manipulation, and display of System data. Four System programs—FILGEN, MAPMERGE, GRID, and CELUPDAT—perform the first of these functions. The second function is performed by GRID and four other System programs—SEARCH, WINDOW/LIST, LIBRARY LIST, and VARLIST. The following sections discuss the use of these System programs and associated routines.

Data Base Creation and Maintenance Software

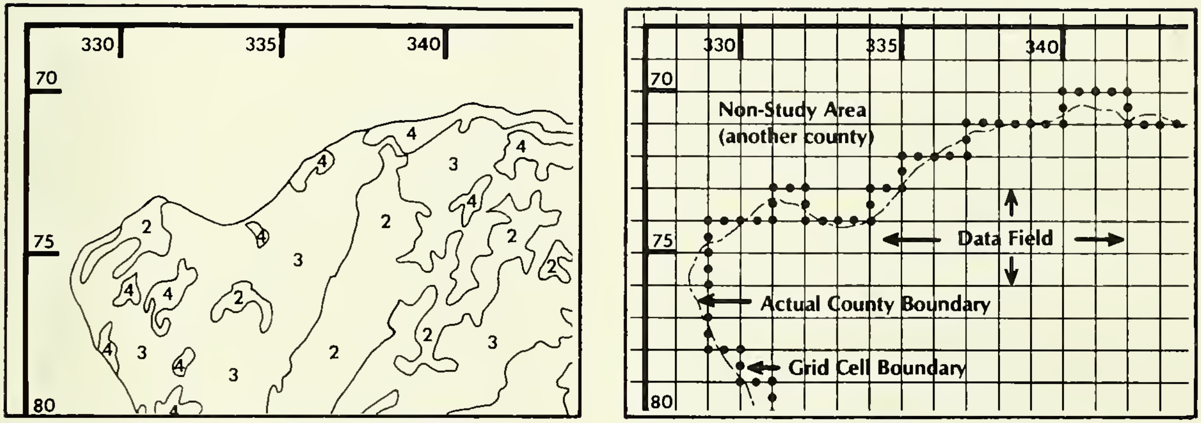
FILGEN. The FILGEN or *file generation* program is used to convert data which has been encoded and keypunched from card images into a computer file. The file is termed a single variable because it contains only the data values for one System variable, arranged in a matrix of rows and columns. The FILGEN program checks the user-supplied input specifications to verify that the correct number of rows and columns and the format has been read by the program.

A routine is used to produce a *FILGEN deck (or window),* which is created for encoding and which is operated on by FILGEN. By supplying the routine with the beginning and end column numbers of each row which contains data in a county cell matrix, the routine produces a form containing a space for data input for each cell in the county. The routine expands the data input space depending upon the number of digits needed to describe the variable. A significant improvement to the System, this routine replaces the manual labor originally required to create a FILGEN deck for encoding. Multiple copies are produced for each county which allow the same form used for a one-digit variable, for example, to be used for another one-digit variable. In Figure 3, part of a FILGEN deck is shown for a one-digit variable to illustrate this data entry technique.

MAPMERGE. After each county single variable file is FILGEN-ed, the MAPMERGE program is used to assemble them into the MAGI System data base. There are two possible approaches to using the MAPMERGE program: (1) county single variable files can be merged together to produce regional or State-wide single variable files, which can then be merged onto an existing regional or State-wide single or multivariable file, or (2) several single variable files for the same county can be merged to form a county multivariable file, which can then be merged with other multivariable county files to form regional or State-wide multivariable files.

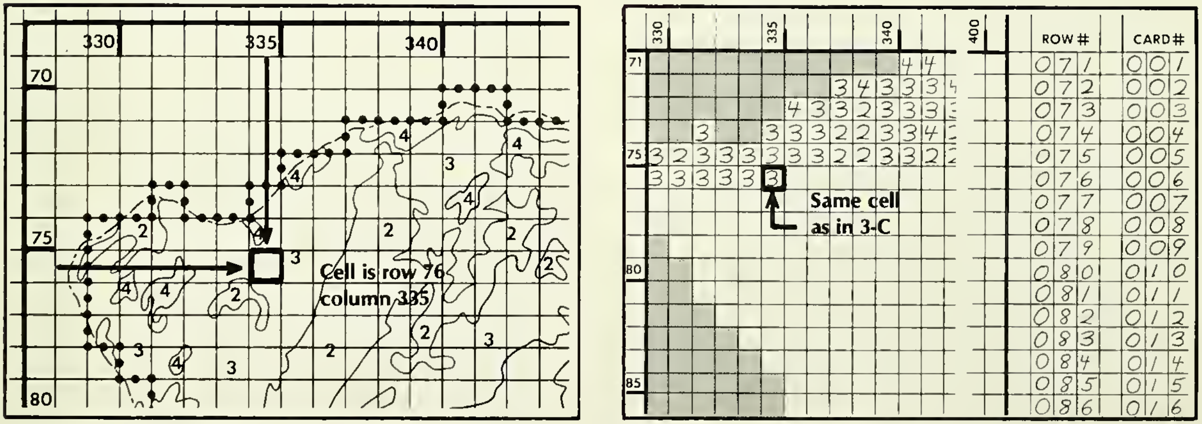
GRID. After data is encoded, keypunched, FILGEN-ed, and referenced to the data matrix by MAPMERGE, the GRID routine is used to display, or map, the single variable files for graphic editing. The GRID program is the heart of the MAGI System software and is a derivative of a program by the same name which was developed at the Laboratory for Computer Graphics and Spatial Analysis at Harvard University. Although the GRID program contains many user options (which are discussed below under manipulation software), the primary use of GRID for graphic editing is to check that a county has the proper cell configuration (i.e., no holes or stray cells), that it is properly positioned within the State matrix, and that all cells have data if they

Figure 3: DATA ENTRY (ENCODING) ON A FILGEN DECK



3-A Example of polygon data map for slope

3-B Grid-cell configuration for area in 3-A. Each square represents one 91.8 acre cell.



3-C Overlay of grid on data map for encoding. Cell outlined (row 76, col. 335) has data value of 3.

3-D Filgen-deck representation of 3-C with primary slope values encoded. Cell outlined is same as in 3-C, and value of 3 is entered on encoding form.

should have data. Errors which are discovered during the graphic edit are usually corrected by CELUPDAT.

CELUPDAT. Multivariable data files can be updated or corrected on a cell-by-cell basis through the CELUPDAT or *cell update* program. Where corrections for areas are not large enough, at least whole counties, to warrant the use of MAPMERGE, the CELUPDAT subroutine is especially useful. Each card in the cell update file contains the row and column of the cell, the position of the variable in the data file, and the new data code for each data value to be changed. A routine is also used to generate a file of update cards where there are blocks of cells (usually 100 or more) in an area to be changed or where the cells or data have some numerical pattern. In addition to CELUPDAT, new single variable data files can be appended to the System data base and all or part of a single variable data file which becomes obsolete as a result of the acquisition of more recent data can be updated via MAPMERGE.

For special projects, the routine ADD-ON is used to read in a complete State-wide multivariable file and write out another multivariable file with a smaller number of variables. For example, a project may require only 6 of the 23 State-wide variables: ADD-ON can be used to structure a multivariable file with only the desired 6 variables. There is considerable potential for time and run cost savings from using this technique as, in the case of this example, the input to the data manipulation is only one-fourth as large, especially if extensive analyses are to be performed. ADD-ON is also used to append a *blank* file of zero values to the State-wide data base. This file can then be filled with data values through the CELUPDAT or MAPMERGE subroutines. For data which are widely distributed but occur infrequently, this procedure is far more efficient than setting up FILGEN decks and merging each county data set.

Another routine, CHANGE-ALL, was developed to permit the values of a particular code within a data variable to be changed to another specified code. This routine is useful if a change must be made State-wide due to a reclassification of codes within a variable. For more complex *renumbering* of data codes, espeically for more than one variable at a time, ADD-ON is used in conjunction with a user-supplied algorithm input via GRID.

Data Retrieval, Manipulation, and Display Software

GRID. Data is primarily manipulated for map display through GRID. This subroutine requires the input of both grid-based data and a map option specification file (MAP-PAK). A user-supplied FORTRAN algorithm is also required for any display other than a default (standard program specification) single variable display or the output from a previous GRID display. Many options are available to the user through GRID for map display including up to 75 separate levels or combinations of data output, up to 50 lines of text/legend, user-specified print symbolism with an overlay of up to four characters, map scale selection (discussed under output products), value range selection, and default specifications. Addition of write statements in the algorithm allow the user to list out cell information for levels with the map, such as a list of erroneous data codes. Default single variable display maps allow the user to simply *dump* a data variable into groups or levels which correspond to a specified number of intervals between specified low and high values of the data range. For example, for slope data where the data codes are the integers from 1 to 4, a simple display map can be produced by input of a MAP-PAK with specifications for the variable position (if it is in a multivariable data matrix), a minimum specified value of 0.5 and a maximum of 4.5, a 4-level specification, and a selection of four print characters. The slope values are then grouped and displayed such that they are in separate levels with different print symbols. If the value ranges and number of intervals are not specified, GRID will create, by default, 10 levels of equal intervals and will supply a standard *grey-tone* symbolism.

More sophisticated multivariable analysis requires the input of an algorithm which selects, sorts, or combines data codes of several variables and assigns them to specified map output levels. An example of a typical algorithm to display the present and planned uses of Maryland's agricultural soils is presented in Figure 5. The map display from this algorithm is presented in Figure 4. Where specific data relationships are known, data codes can also be weighted both within and among variables to yield a display which is more representative of a *model* of conditions. The output files from previous algorithms can also be used as input (*read-ins*) to other algorithms to reduce the complexity of manipulations within one algorithm or to account for a previously established relationship. The primary advantage of *read-ins* is reduced computation time and cost. Such algorithm *pyramids* are frequently used to produce composites of several data analyses.

SEARCH. The SEARCH subroutine is used either to identify the minimum distance from each cell to the nearest cell with a particular data value or to identify the frequency of occurrence of a particular data value within a given radius from each grid cell. This program, which becomes costly as the minimum search distance or radius increases, is used primarily to determine accessibility, or to indicate a *distance-decay* (gravity) function. The output can be displayed with the same GRID options through a MAP-PAK or can be used as input to another algorithm. An example of a 13-cell search to primary and intermediate arterials is presented in Figure 6.

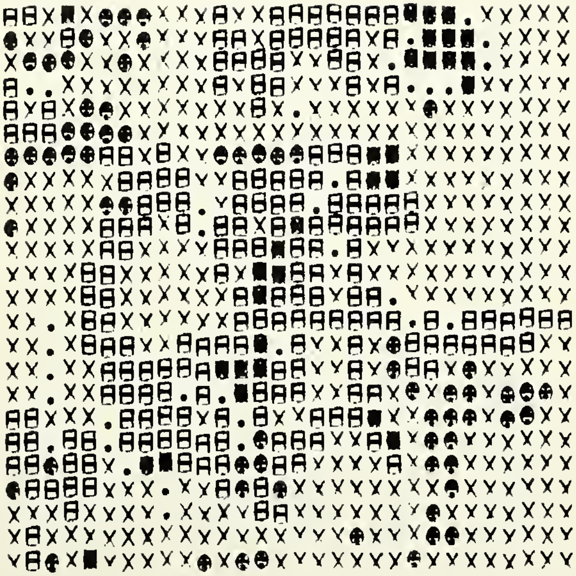
WINDOW/LIST. Although each of these programs can be used independently, they are commonly executed simultaneously through user options in the programs. A smaller multivariable data file can be separated or retrieved from a larger file via WINDOW. Common *windows* are counties or regions from the State-wide data base or special configuration study areas. For the latter, the program operates by specifying the beginning and end column numbers for each row or groups of rows of the smaller area in the larger data matrix. For county or regional windows, an option allows the user to directly specify the county codes desired, and all cells with those codes are windowed. The value of WINDOW is the potential cost savings of manipulating only the section of the data base which is required. The effect of windowed files on execution costs is discussed below.

Once a subfile is created, it can be dumped via LIST in a format which prints all the data values for each cell on one or two lines. County-wide listings are most often used for spot-checking data values, obtaining data for very small areas where use of the System would not be warranted, and keeping record of data updates or error corrections.

LIBRARY LIST. Four LIBRARY programs are used to retrieve detailed information about sites inventoried for the historic sites, archaeological sites, public land ownership, and unique natural features/scenic areas data variables. Each LIBRARY LIST program requires as input a library file which contains a site identifier and detailed information for each site. The site identifiers are structured for sorting, which is performed by specifying desired information on option cards for the LIBRARY programs. The types of information which can be retrieved are discussed above under the variable descriptions.

VARLIST. The VARLIST or *variable listing* routine is used to produce tabular summaries of a single variable data file or the output from GRID. For each output level in a file or on the display map, VARLIST indicates the cell frequency, calculates the area in acres or square miles, and lists the percentage of the total number of cells in the study area which were assigned to that particular output level. VARLIST requires as input both the file to be summarized and an areal file by which the tabulations are to be made. Summaries are usually calculated for counties/regions, watersheds, or census tracts/minor civil divisions. In addition to summaries by areal unit, VARLIST provides a summary for the entire study area.

Actual size of print symbols in Figure 4



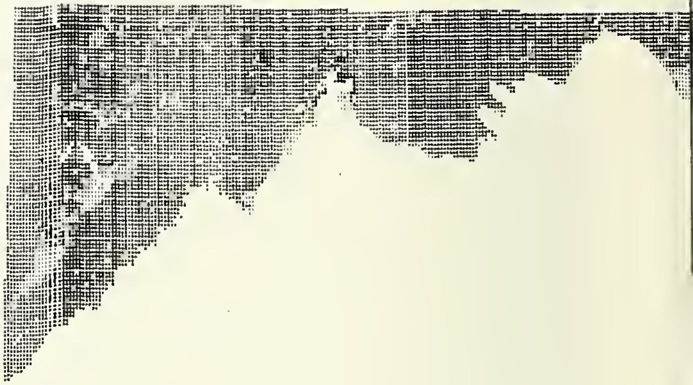
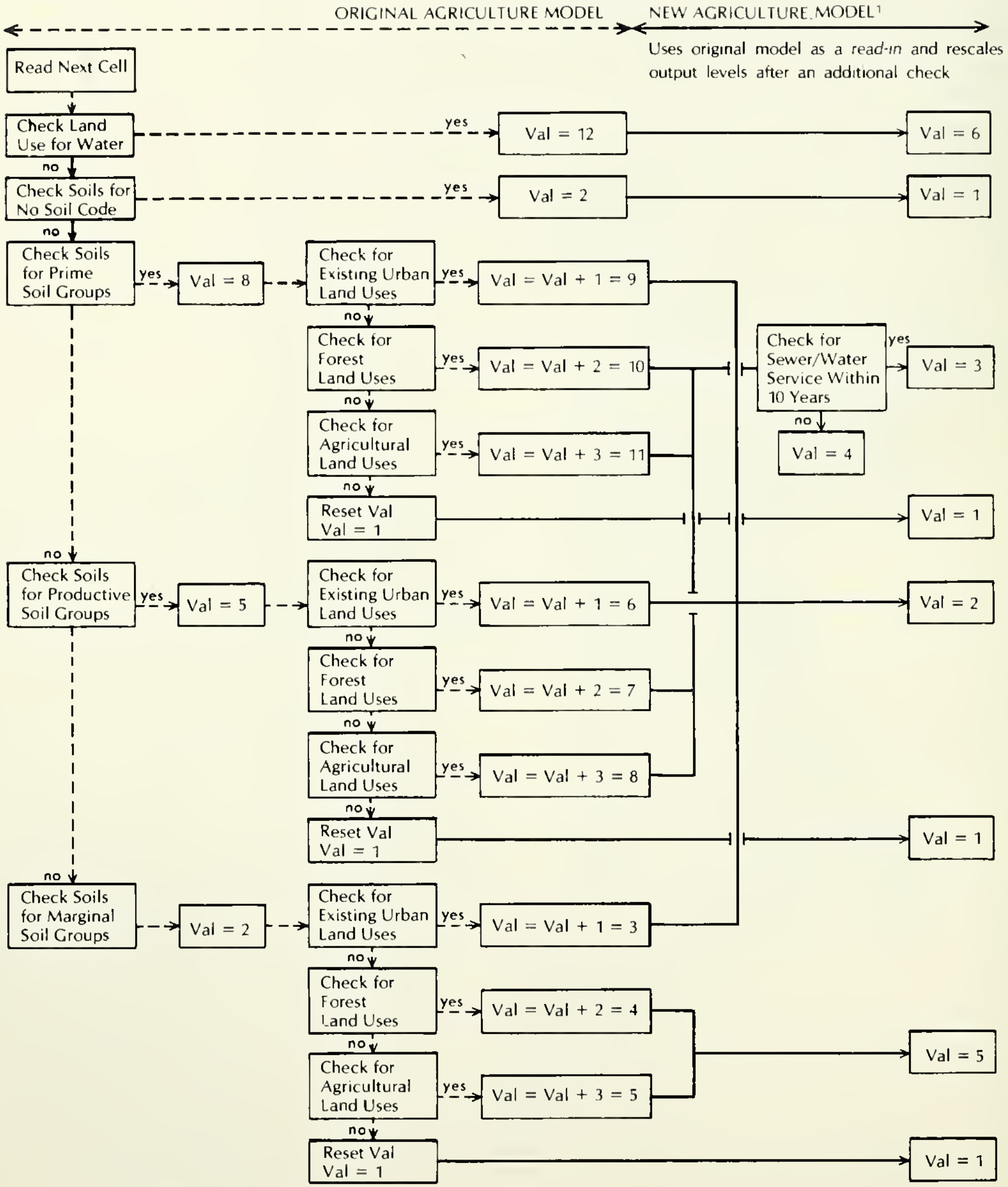


Figure 4: A TYPICAL LINE-PRINTER MAP SHOWING THE USE OF AGRICULTURAL SOILS

▥	Prime, productive, and marginal soils in urban land uses within and beyond a ten-year sewer/water service area	Val = 2
▤	Prime and productive soils in agricultural and forest land uses within a ten-year sewer/water service area	Val = 3
░	Prime and productive soils in agricultural and forest land uses beyond a ten-year sewer/water service area	Val = 4
▦	Marginal soils in agricultural and forest land uses	Val = 5
	All other areas (prime, productive, and/or marginal soils in other than agricultural, forest, or urban land uses) or soil not rated	Val = 1
☐	Water	Val = 6

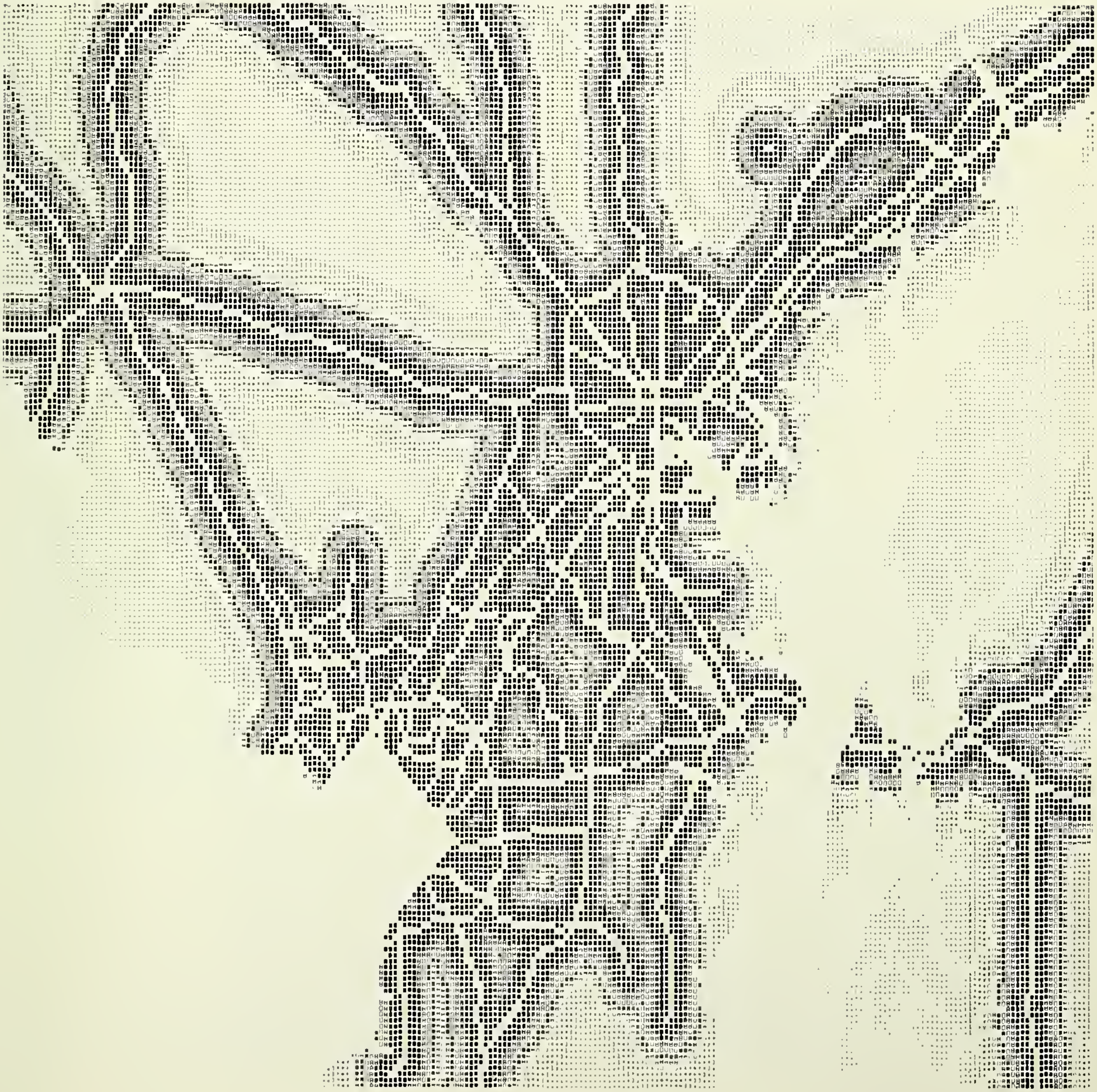
NOTE: Value levels shown are as calculated by algorithm in Figure 5.

Figure 5: A TYPICAL ALGORITHM


ORIGINAL AGRICULTURE MODEL
NEW AGRICULTURE MODEL[1]
Uses original model as a *read-in* and rescales output levels after an additional check
Read Next Cell
Check Land Use for Water
yes
Val = 12
Val = 6
no
Check Soils for No Soil Code
yes
Val = 2
Val = 1
no
Check Soils for Prime Soil Groups
yes
Val = 8
Check for Existing Urban Land Uses
yes
Val = Val + 1 = 9
no
Check for Forest Land Uses
yes
Val = Val + 2 = 10
no
Check for Agricultural Land Uses
yes
Val = Val + 3 = 11
no
Reset Val Val = 1
Check for Sewer/Water Service Within 10 Years
yes
Val = 3
no
Val = 4
Val = 1
no
Check Soils for Productive Soil Groups
yes
Val = 5
Check for Existing Urban Land Uses
yes
Val = Val + 1 = 6
Val = 2
no
Check for Forest Land Uses
yes
Val = Val + 2 = 7
no
Check for Agricultural Land Uses
yes
Val = Val + 3 = 8
no
Reset Val Val = 1
Val = 1
no
Check Soils for Marginal Soil Groups
Val = 2
Check for Existing Urban Land Uses
yes
Val = Val + 1 = 3
no
Check for Forest Land Uses
yes
Val = Val + 2 = 4
no
Check for Agricultural Land Uses
yes
Val = Val + 3 = 5
Val = 5
no
Reset Val Val = 1
Val = 1

[1] Map display from this algorithm is shown in Figure 4

Figure 6: A 13 CELL SEARCH TO PRIMARY AND INTERMEDIATE ARTERIALS



Output Products and Scales

A variety of output products and formats is available to MAGI users depending upon the particular requirements of the user's data request. These include (1) line printer maps at several scales, (2) line printer tabulations of output calculations, (3) DICOMED recorder film, and (4) CalComp electromechanical plotter maps. These products are discussed in the following sections.

(1) The most commonly used and economical output device for output maps is the standard line printer. Because the 91.8 acre State-wide data cells are square and because the line printer characters are not square (1/10 inch horizontal × 1/8 inch vertical), output maps for which one print character represents one cell are therefore distorted (elongated) in the vertical dimension. State-wide 91.8 acre-based maps have a scale of 1:240,000 (1 inch = 3.79 miles) horizontally and 1:192,000 (1 inch = 3.03 miles) vertically. However, the MAGI software allows the user to have each cell represented by more than one print character to correct for scale. This is of value when the user has need to overlay acetate sheets showing locations of towns, roads, streams, or other features.

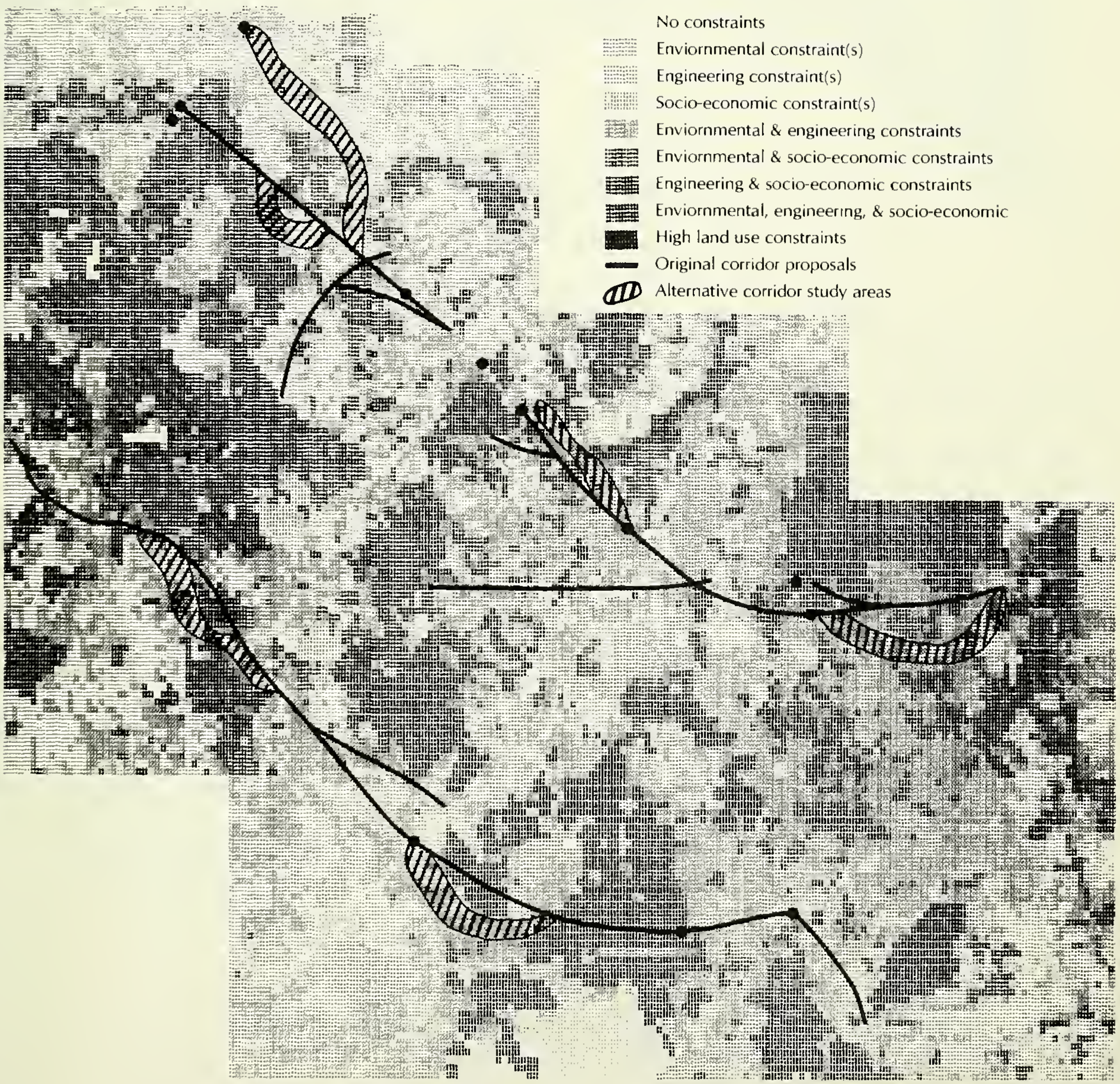
There are two commonly selected alternative output scales which produce cell configurations of equal horizontal and vertical scale. One option, termed the *2 × −2*, represents each MAGI cell by a staggered sequence of 2 × 2 and 2 × 3 characters, producing an overall scale of 1:96,000 (1 inch = 1.52 miles). While there is some visual distortion in this configuration because at scale each cell would be an average of 2 × 2.5 cell blocks, it is usually not significant and is easily interpreted by the user. A second option, termed the *4 × 5* or *8 × 10*, represents each MAGI cell by a block of print symbols arranged 4 down by 5 across or 8 down by 10 across. The resulting scales of these maps are 1:48,000 (1 inch = 0.756 miles) and 1:24,000 (1 inch = 0.379 miles), respectively.

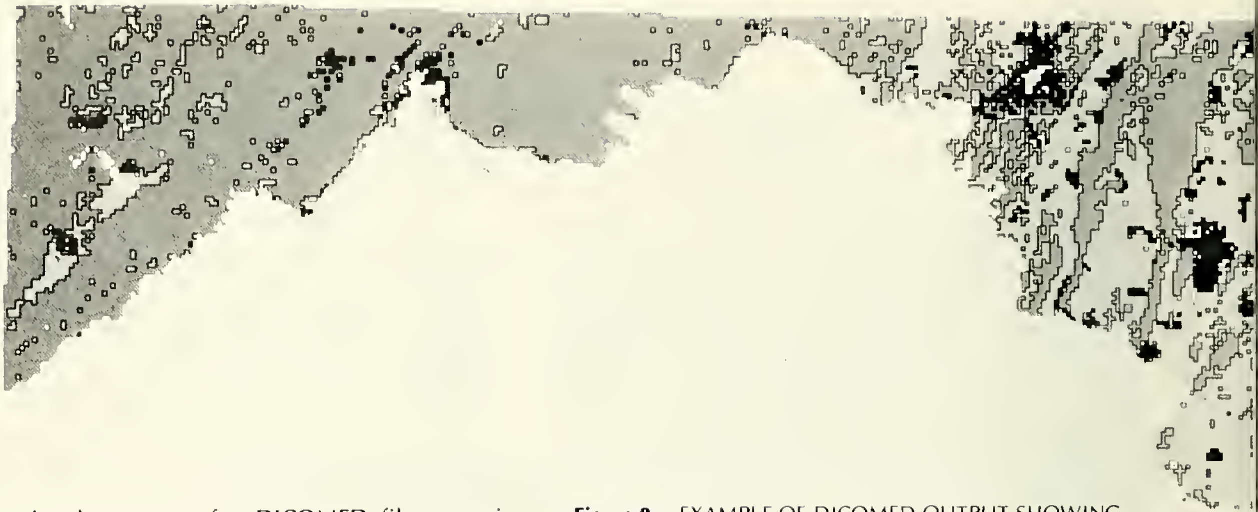
The special area data bases at 4.57 acres do not have scale distortion because the cells are rectangular in the same ratio as the print characters. Maps are usually produced according to the *1 × 1* option at a scale of 1:48,000 (1 inch = 0.756 miles) and the *2 ×* 2 option at a scale of 1:24,000 (1 inch = 0.379 miles). An example of a map display using the *2 × 2* option is presented in Figure 7.

(2) The MAGI output maps have a legend which tallies the number of cells which have been assigned to each output level. Users often desire to know the spatial distribution of the mapped phenomena by county, region, election district, census tract/minor civil division, or watershed. By combining the output file of the calculated map values with an areal file, it is possible to obtain a tabular summary through the VARLIST program, as previously described.

(3) High quality black and white or color reproduction of MAGI output maps for mass production is possible with the use of the DICOMED image recorder. Similar to the line plotter, the map output file must be converted with software for the DICOMED process. The DICOMED retains the cell boundary configurations but rectifies them to squares and enhances their visual appearance by assigning a solid user-specified color to the entire area of cell blocks with the same output value. To date, these services have been secured by contract. The average cost for file conversion and production of a 4 × 5 inch color negative for a State-wide data map is discussed under System costs. A reproduc-

Figure 7: A TYPICAL HIGHWAY CONSTRAINT AND POTENTIAL CORRIDOR MAP USING A 2 × 2 OPTION


No constraints
Enviornmental constraint(s)
Engineering constraint(s)
Socio-economic constraint(s)
Enviornmental & engineering constraints
Enviornmental & socio-economic constraints
Engineering & socio-economic constraints
Enviornmental, engineering, & socio-economic
High land use constraints
Original corridor proposals
Alternative corridor study areas



tion and enlargement of a DICOMED film map is illustrated in Figure 8.

(4) Upon request, MAGI output files can be interfaced with basic CalComp software and can be output on standard drum or flat bed electromechanical plotters. In addition to producing black line plots of MAGI output of up to 75 levels with registration marks and a legend, the capability exists to plot 3-color maps. An example of a CalComp plot display is presented in Figure 9.

Figure 8: EXAMPLE OF DICOMED OUTPUT SHOWING THE USE OF AGRICULTURAL SOILS

▓ Prime, productive, and marginal soils in urban land uses within and beyond a ten-year sewer/water service area

■ Prime and productive soils in agricultural and forest land uses within a ten-year sewer/water service area

░ Prime and productive soils in agricultural and forest land uses beyond a ten-year sewer/water service area

▒ Marginal soils in agricultural and forest land uses

☐ All other areas (prime, productive, and/or marginal soils in other than agricultural, forest, or urban land uses) or soil not rated

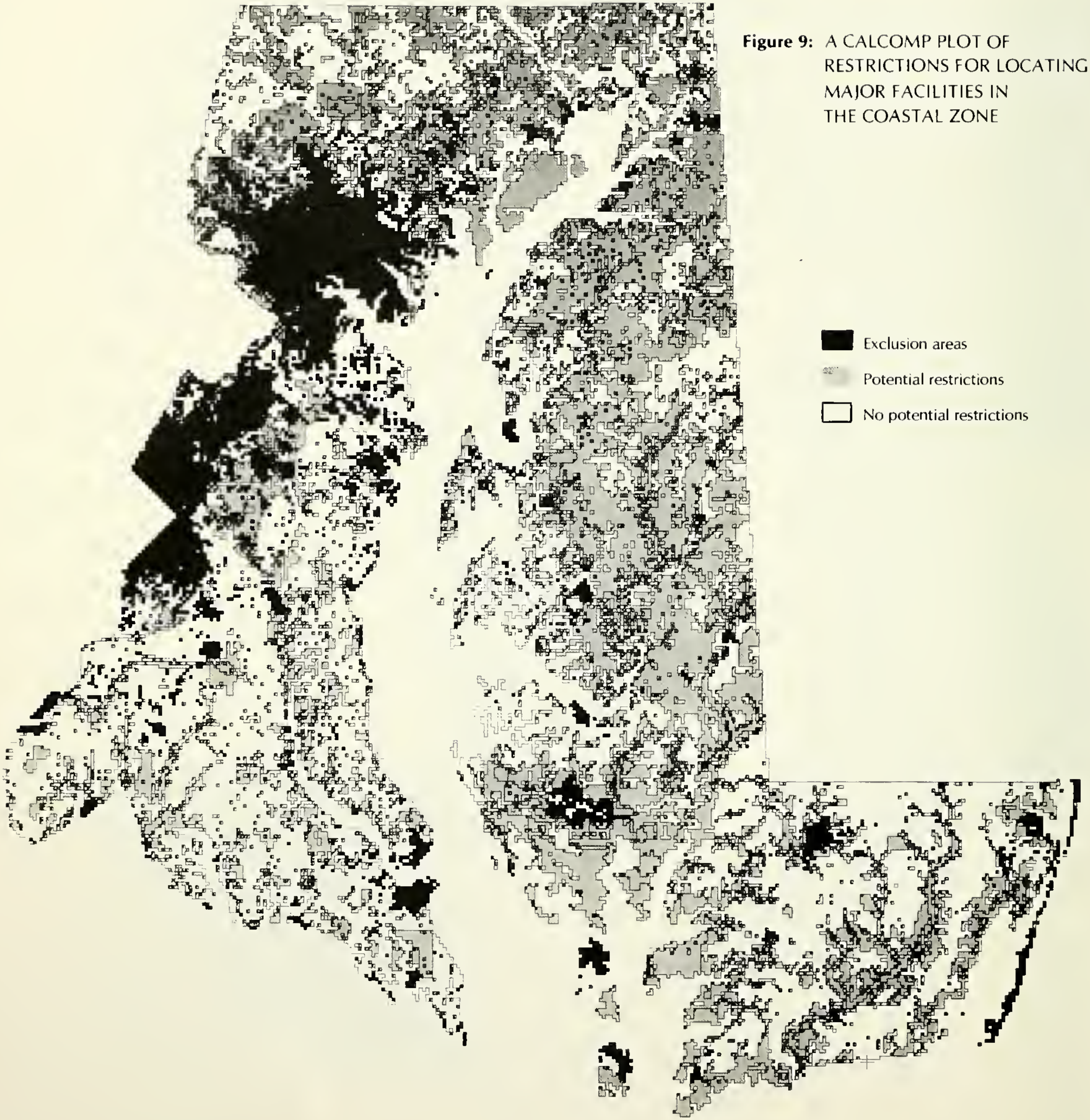


Figure 9: A CALCOMP PLOT OF RESTRICTIONS FOR LOCATING MAJOR FACILITIES IN THE COASTAL ZONE

Ancillary Programs and Capabilities

There are several programs and computer capabilities which were not originally part of the MAGI System but which are now associated with its application to planning problems. The most important of these include (1) the interface of MAGI with Landsat; (2) AUTOMAP II; (3) supplementary GRID routines, including Slope/Aspect and Cut/Fill Analysis; and (4) capabilities through the Statistical Package for the Social Sciences (SPSS). The following sections briefly describe each of these ancillary capabilities.

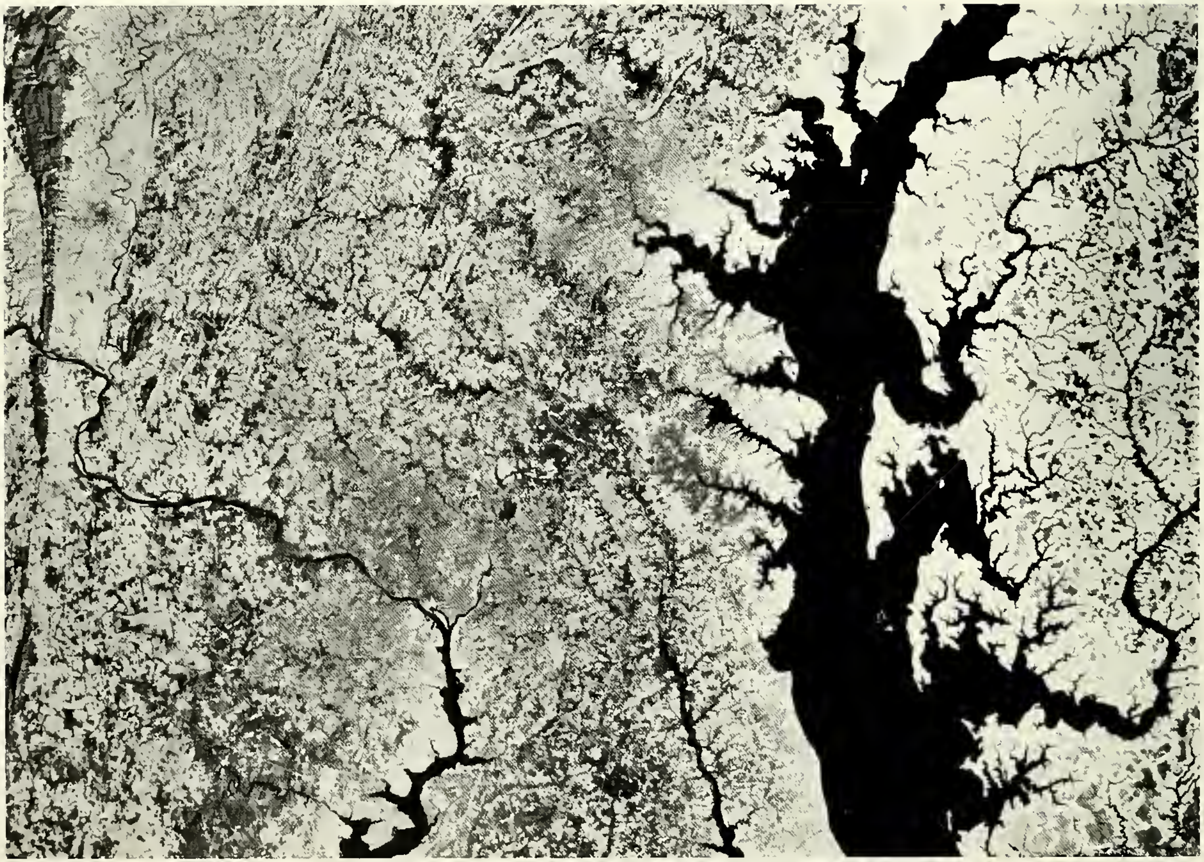
Landsat. The Department is currently working with NASA to develop software which will allow land use information from satellite-generated computer compatible tapes (CCT) to be directly interfaced with the MAGI grid system. The information, which is recorded by pixels, will be aggregated to 4.57 acre grid cells and their respective 91.8 acre grid cells. Unlike rather static physical data variables such as soils, slope, or geology, land use and land cover is a dynamic cultural variable. The frequency and pattern of coverage of the Landsat system can provide this type of continuous data. There are a variety of potential applications that may benefit from integration of Landsat with MAGI, including land use monitoring, forest inventory, and strip mine and water quality monitoring.

AUTOMAP II. Automap consists of three related programs which produce choropleth, contour, or proximal maps. The BASE-MAP program is the core of the package and serves to set up the coordinate locations of areas to be mapped for a given variable. The variable to be mapped is specified in the AREA-MAP or CONTOUR/PROXIMAL-MAP programs, which are linked with the BASE-MAP's Image File (BMIF) to produce a display. The three types of maps produced through AUTOMAP II differ from GRID-based displays in that they allow values to be displayed for each cell even when every cell in the AREA-MAP or CONTOUR/PROXIMAL-MAP file do not have values. Choropleth mapping displays quantitative or qualitative data for an entire areal unit, such as census tract or county, based on the association of a data value for the area and the set of cells which form the boundary of that area. Contour mapping is used to display a three-dimensional *data elevation* surface by interpolating grid cell values and calculating contour or *equal-value elevation* planes. Noncontinuous data is mapped using a single value for an areal unit through the PROXIMAL-MAP program. Data polygons are formed by searching to find the shortest distance from each grid cell to a point with a data value. Each cell is thereby assigned the value of the nearest cell with a value.

Supplementary GRID routines. The Slope and Aspect routines read a file of elevation data and produce displays useful for evaluating the steepness or orientation of slopes for potential uses. Cut/Fill analysis is performed by a routine which simultaneously reads existing and proposed elevation (topographic) data files. Elevation differences are calculated for each cell and the difference is multiplied by the cell area to determine the volume of cut or fill. The output can qualitatively relate cut areas to fill areas or can separately provide quantitative data on cut or fill areas.

SPSS. For algorithms whose output reflects weighted scores, there are standard statistical programs available through the University's SPSS library. The output files from weighted algorithms can be analyzed to determine the difference between weight sets. Among the more-familiar SPSS programs are those for descriptive statistics, frequency distributions, cross tabulations, correlation, analysis of variance, multiple regression, discriminant analysis, and factor analysis.

Landsat scene showing the Baltimore-Washington corridor and the upper Chesapeake Bay area.



System Costs

An information system such as MAGI requires a substantial initial investment and operating support. However, the cost savings due to computerized data retrieval, analysis, and display are certainly many times these costs, especially if compared to the time and material costs of manual labor. This section summarizes the initial System development costs and typical costs of operations. The latter is especially useful to the potential user.

The costs, both in manpower and dollars, of establishing the MAGI System varied by the type of task involved as well as the data variable being worked on. These variations reflect not only the complexities of the data but also the many idiosyncrasies either in the initial data collection or in display format or scale. The initial data collection involved encoding or digitizing nearly 88,000 grid cells for 24 variables, including primary, secondary, and tertiary levels. Approximately 400 maps were used for data input. Some variables did not have full coverage and many did not have values in all cells or for all levels of encoding. Consequently, the total number of data occurrences recorded was approximately 800,000. In Table 2, the total costs and percentage of initial System cost for all variables is presented according to nine general tasks. In addition to these initial costs, a considerable expenditure of labor and computer funds were needed to convert and debug programs. The current cost of establishing the MAGI System could reasonably be expected to be at least two times the original cost.

Table 2: SUMMARY OF INITIAL MAGI SYSTEM DEVELOPMENT COSTS

ITEM	% OF TOTAL INITIAL COST	TOTAL COST FOR ALL 24 VARIABLES
Data Identification and Acquisition	4.6	$ 9,250.
Analysis and Reformatting	39.1	$ 78,950.
Encoding and Editing	21.8	$ 44,005.
Library Referencing	2.7	$ 5,350.
Preparation of Materials	11.1	$ 22,300.
Data Management	8.6	$ 17,400.
Computer Software Development and Documentation	3.9	$ 7,940.
Merging and Correction of Data Files	5.4	$ 10,835.
Final Implementation and Testing of System	1.6	$ 3,200.
Computer Models	1.2	$ 2,500.
Total Cost	100.0	$201,730.

The average execution costs for typical applications of the MAGI System vary according to the area being manipulated, which translates to the size of the multivariable file and the particular program being executed. In Table 3, some average execution costs are indicated, based on current University *run time* costs.

While Table 3 has been structured to give an estimate of the potential execution costs of using the MAGI System, there are other associated costs which are not as easily estimated. For example, Departmental labor for programming, System operation, and any data compilation and encoding are also involved and are billed to the user when a request for services is made. There are further costs involved with nonexecution computer functions such as card reading/punching, file editing, and tape assignment and copying. The University also charges for services such as consultation, keypunching, tape storage, and output paper. More detailed information about how the user can estimate service request costs is discussed in the section on how to use the MAGI System.

Table 3: AVERAGE EXECUTION COSTS FOR TYPICAL COMPUTER TASKS[1]

State-wide GRID execution, with algorithm		$ 35.
• additional cost per input of previous GRID output		$ 6.
Regional GRID execution, with algorithm		$ 6.
County GRID execution, with algorithm		$ 1.
• Costs for above are for "1 × 1" scale option, double or more for larger-scale options		
WINDOW a region from the State-wide file		$ 12.
Execute a 13-cell State-wide frequency SEARCH		$ 55.
VARLIST a State-wide output, by county		$ 5.
• by watershed		$ 15.
• by election district		$ 25.
Plot of State-wide GRID execution:		
GRID execution	$ 35	
Tape creation	$ 15	
Plot	$150	$200.
DICOMED of State-wide GRID execution:		
GRID execution	$ 35	
Set-up, per batch	$200	
DICOMED, per GRID	$125	$360.
• 5 to 6 GRID executions can be DICOMED-ed per set-up.		

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[1] Costs do not include Departmental charges for labor for programming, encoding, and System operation; other University charges for non-execution computer costs (tape assignment and copying, file editing) and user services (keypunching, consultation, tape storage, output paper) are also not included. These costs represent averages and may be more or less, depending on the size and scale of the study area, and the complexity of algorithms and number of variables used.

System Applications

The MAGI System was originally developed to assist the Department of State Planning in the preparation of its Generalized State Land Use Plan (GSLUP). The requirements of this effort for immediate information needs, including factors of time, cost, and available data, have determined the size and level of detail of the System. While the System which was developed as a result of these factors necessarily entails limitations for some types of planning and analysis, especially detailed site analysis, it does have a considerably broad utility. A host of effective and efficient applications of the System within Maryland are possible, and to date this potential has been successfully tapped by users at several levels of government and the private sector. The purpose of this section is to highlight some of the applications of the MAGI System in order to provide potential users with a better understanding of the System's capabilities and limitations.

Recent applications of the MAGI System can be grouped into several user levels, including use by the Department of State Planning, other State Agencies/Departments, local governments, and the private sector. Major uses of the System within the Department of State Planning in addition to preparation of the GSLUP have been the preparation of the State Comprehensive Outdoor Recreation Plan (SCORP) and the Quad County/Laurel Study. The Energy and Coastal Zone, Water Resources, and Wildlife Administrations of the Maryland Department of Natural Resources have used the System extensively. Other users have included the Soil Conservation Service office of the U.S. Department of Agriculture, the Maryland Department of Agriculture, the State Highway Administration of the Department of Transportation, the Baltimore Regional Planning Council, and the Departments of Geography and Recreation of the University of Maryland. Baltimore, Carroll, and Howard Counties have also used MAGI directly for local environmental studies, through their planning or public works agencies. Limited use has been made of the System by the private sector to date, except for one major project under contract to a State agency.

These applications have employed varying levels of detail in their analyses and have exhibited diversity in the size and scale of the study area, the number of variables used, the complexity of variable combinations, and the purpose or subject of the analysis. The following sections highlight some of the applications which have been made of the MAGI System for a variety of planning studies.

Land Use

The Department of State Planning has primarily used the MAGI System to prepare its Generalized State Land Use Plan. In an extensive effort that lasted several years, the System was used to evaluate the location and potential of the State's prime natural resources, the pattern and extent of existing urban development, and planned facility service areas. A series of maps was produced and combined to construct a composite map of these conditions. The composite was used as a final base map for further policy-guided, manual allocation of four alternative patterns of planned growth. The alternative growth allocations were then encoded and evaluated against the resource base to determine the amount of various resource areas consumed for each alternative. Many of the State-wide maps produced for the Plan documents were DICOMED-ed.

For the major natural resources—agricultural soils, forests, minerals, wetlands, and unique natural features and scenic areas—maps were produced which illustrate the existing and potential resource areas. Often, where the resource areas could be distinguished by degrees of quality, the best or prime resource areas were selected for combination with other resources in the composite.

Existing urban development and planned facility service areas were composited with the resource areas to indicate places where development conflicts with prime resource areas and places where planned growth can be located without adversely impacting valuable resource areas. A major strategy of the future growth allocation was to concentrate growth in areas which were already partially developed. To do this, an estimation procedure was developed by examining the multiple levels of land use occurrence to determine the percentage of each cell with an urban land use that remained undeveloped.

Agriculture

The State's Executive and Legislative committees on the Preservation of Agricultural Land relied on the technical assistance of the Department in compiling and assessing the available data on the current trends and probable future directions of agricultural land use in Maryland. The Department produced computer-generated maps, by county, as a basis for analyzing farmland and its location, quantity, and vulnerability to change through urban development. For these maps, natural soil groups were evaluated according to their limitations and suitabilities for intensive cropping. The soils were labeled prime, productive, and marginal, reflecting the range of soils from those best suited for farming to those least suited for farming. The current use of these soils for other uses such as forest, urban, or wetlands was then evaluated. Finally, as a measure of the probable vulnerability of currently undeveloped prime and productive soils to future encroachment by urban uses, their location within or beyond county-designated ten-year sewer/water service areas was determined.

Wildlife

As part of a wild turkey restocking program by the Maryland Wildlife Administration, the MAGI System was used to classify and quantify the occupied and potential range of wild turkeys in Maryland. Criteria such as present locations of turkey populations, turkey habitat requirements, and human activity constraints were defined to determine levels of potential wild turkey habitation. By weighting land use, natural soil groups, forest cover, and county-proposed ten-year sewer/water service areas, high, low, and nonpotential habitat areas were mapped, as well as existing and future urban areas. To evaluate the criteria and feasibility of the study, four counties throughout the State were selected as test areas. Field checks by Wildlife Administration staff members showed that *modeled* potential areas were adequate for wild turkeys. The entire State was then evaluated, and areas indicated as potential habitat were chosen for turkey releases.

The success of this project led to the initiation of more extensive efforts to tie the Wildlife Administration's management system for some 500 species of wildlife into the MAGI System. In addition to producing displays of recorded sitings of these species, potential habitat ranges will be determined. The Administration's Wildlife Distribution Survey will further permit timely retrieval of data for environmental impact review for applicable projects. The Survey will initially incorporate up to 500,000 sitings, each consisting of the species sited, date of observation, number of animals sited, location coordinates, and data source. The System will permit listings of all species observed across the State or within a geographical area with the potential of up to 100 species and 500 sitings per grid cell. Maps will also be produced showing all cells in which a given species or species group has been observed. The retrieval will allow data to be listed or mapped for individual species as well as major associations (birds, mammals, reptiles, amphibians, fish, and invertebrates) and for management classes (game, non-game, endangered, and threatened).

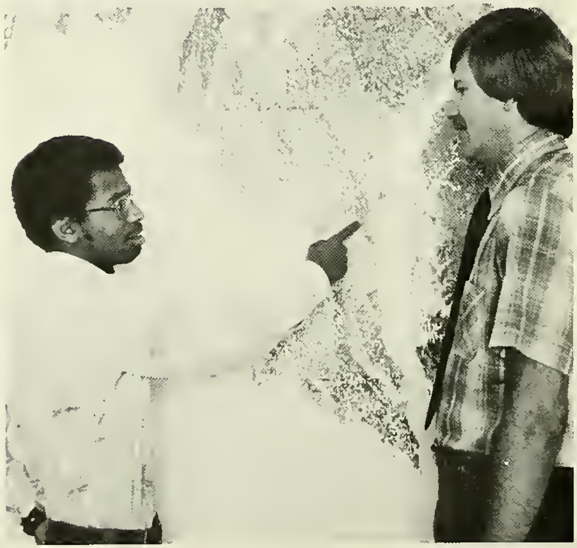
Transportation

The State Highway Administration's Bureau of Landscape Architecture has used the MAGI System for several projects involving environmental assessment of potential highway relocation corridors. For most of these projects, small areas were considered and data was encoded by 4.57 acre cells. The environmental assessments considered major physical, cultural, engineering, and biotic constraints for highway location. For example, soils, slope, and engineering geology are often used to assess soil erosion; excavation requirements; stability of cut faces; limitations due to shallow soil, high frost heave potential, high water table, or susceptibility to seepage; suitability as a source of roadfill; and embankment compaction and stability. By weighting the number and types of constraints, relative construction costs were determined and were mapped as composites with other physical, cultural, or biotic variables. The Bureau has used MAGI and this process not only to evaluate proposed alignments but also to identify potential corridors, as shown in Figure 7.

Major Public Facilities

The Energy and Coastal Zone Administration of the Maryland Department of Natural Resources conducted an extensive study, under contract to a private consultant firm, to develop and test a method for locating major public facilities in the coastal zone of Maryland. The method which was developed involved a screening process to determine candidate areas where facilities might be located after detailed study of these areas. Locational criteria for a variety of facilities were defined and mapped to identify several candidate areas, including energy related facilities (outer continental shelf related, electric generating, and liquid natural gas facilities), commerce related facilities (ports and industrial parks), sand and gravel extraction facilities, major residential facilities, and major recreational facilities. Candidate areas were defined in terms of compatibility of major facilities with the existing resource base and the economic, environmental, and fiscal objectives of the State.

A large amount of computer *modeling* was employed in the process, an example of which is shown in Figure 8. In addition, the SEARCH routine was used extensively to determine gravity constraints, such as distance of population from power plants or distance of potential areas from surface water as a source for cooling. The coastal zone study also resulted in the updating of several of the System variables and in the inclusion of the Chesapeake Bay bathymetry variable.



How to Use the Magi System

Access to the MAGI System by non-Department of State Planning users follows a straightforward procedure established by the Department. When interest is expressed by a potential user, System staff meet with the user and give a short presentation of MAGI and its capabilities. The needs of the user are also ascertained and an indication of the ability to perform the analysis via the System is given by the staff. The user is then requested to formulate more specifically the service and products requested, especially the size and level of detail of the study area, the number of algorithms and their complexity, and the time frame of the project. The System staff estimate the costs of operator and programmer labor, special data set up or updating, and computer execution and associated run time. These costs and an indirect cost of 17% for System development and maintenance are totaled and suggested to the user to assist in arranging funding.

Often, the Department will share the costs of new data inclusion with a user if it can be determined that the data will be of immediate usefulness to the Department. Options concerning the advantages and costs of performing encoding or other manual labor through arrangements of the user or by Department staff are discussed. Upon agreement to service a request and a commitment by the user to reimburse the Department for costs, the Department establishes a separate user subaccount for the System and performs accounting for the project as it progresses. Finally, an itemized bill is prepared for the user and is delivered with the completed output.

Users may also take advantage of the products of previous analyses. If the data anlysis that a user desires has already been performed, copies are made available at direct execution cost, thereby saving the additional cost of programming and nonexecution computer functions. The System staff inform the user during the first meeting of all previous output products which are similar to the request.

Appendix

Where possible, MAGI System data are input as positive integers to maximize storage capacity. The data are also structured to allow maximum flexibility for user interpretation. For example, the natural soil groups are structured such that the first alphabetic (A-H) describes the general drainage characteristics of the soils, and ranges from the best drained soils (A) through alluvial soils (G) and stony land (H). The second-position numeric (1-3) represents general permeability limitations, ranging from slight limitations or good permeability (1) to very slow permeability (3). The last character of the natural soil group code, the lower case alphabetics (a-c), represents soil slope phases. This ranges from lower slopes of 0 to 8 or 10% (a) to slopes steeper than 15% (c). Natural soil groups are input such that the alphabetic character is associated with its numeric sequence in the alphabet. Natural soil group A1a becomes data code 111 (A=1), B1c becomes 213 (B=2, c=3), and so on.

This type of structuring and data input allows the user to do more than merely identify soil groups. In addition to combining various natural soil groups according to interpretations or limitations for various uses, a FORTRAN modular function can be employed to directly sort soils and group them by slope phase, drainage, or permeability characteristics. The interpretations available from the single natural soil group code are numerous and permit them to be grouped according to estimated soil limitations and suitabilities for the following uses: dwellings; septic tank absorptions fields; local road and street construction; excavations; sources of sand, gravel, and roadfill; sanitary landfills and liquid waste disposal; intensive cropping; tent and trailer use areas; golf fairways and lawn and landscaped areas; and ponds and shallow water developments.

Although the interpretations are greatest for the natural soil groups variable, most of the System variables allow some interpretation from the numerical code through the modular function.

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